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THE ANCIENT KOBUK GLACIER OF ALASKA

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Between Hotham Inlet and Kotzebue Sound, on the Arctic coast of Alaska, there is a long narrow strip of rolling upland which is probably (in part at least) a glacial moraine. The portion I saw in the summer of 1906 (from Cape Blossom north) consists of broad, smooth ridges, probably rising 50 to 150 feet above sea-level, bordered on the west and north by a sea-cliff from 30 to 100 feet high. The tundra vegetation on the upland surface completely obscures the nature of the underlying material, but its character may be inferred from many fairly good exposures in the sea-cliff.

The northwestern corner of this upland is protected from present marine erosion by a triangular strip of lowland bordered by a beach ridge from 5 to 12 feet high, behind which there are lagoons and marshes. The Friends' Mission at Kikiktak or Kotzebue Post-office is situated on the beach ridge near where it makes a sharp bend from north to east and about one and one-half miles from the old sea-cliff. The latter, where thus protected, is broken down and tundra-covered so that there are no satisfactory exposures of the underlying material.

About two miles east of the mission, the cliff presents, along a distance of half a mile, a number of imperfect exposures of typical till. It is a stiff blue-gray clay abounding in rock fragments in sizes up to eighteen-inch boulders. They consist of many rock species, but varieties of gabbro, probably derived from Mendenhall's Kanuti series,[1] are the most conspicuous. Most of the pebbles, cobbles and boulders are somewhat rounded, in the manner characteristic of glacial abrasion, noticeably differing from similar material after having been exposed for some time to wave action on the beach. Very many of the faceted pebbles and boulders are striated; indeed, a few minutes' search yielded some of the finest scratched stones I have ever found.

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[1] Walter C. Mendenhall, "Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, by Way of Dall, Kanuti, Allen and Kowak Rivers," U. S. Geological Survey, *Professional Paper No. 10.*

Owing to the masses of tundra soil that have fallen down the cliff, the upper limit of this apparent glacial deposit is obscured but appears to be quite irregular. It is overlaid by a thick bed of dark blue-gray laminated silt and muck, which is better exposed than the boulder clay. In places the silt forms steep banks 30 feet high, reaching down to sea-level. In other places the boulder clay reaches from 3 to 6 feet above the water and at one place fifteen feet, being there overlaid by only about ten feet of silt. The fine lamination, absence of gravel or coarse sand, and the presence of much peat in the silt at first suggested to me that it was deposited in a lagoon (at a time the land was lower) behind a beach ridge which has been completely destroyed by marine erosion.

The boulder clay has a character typical of ground moraine and it is undoubtedly due to ice action. However, the question may be raised as to the method of its formation and how it reached its present position. This is especially pertinent in view of the fact that this locality is far beyond the reputed limits of Quaternary glaciation in northern Alaska. Three hypotheses are worthy of consideration. The first attributes the boulder clay to the action of shore ice. This would not account for the presence of the clay and the extensive faceting and scratching on all sides of the included rock fragments, for it is inconceivable that the shore ice could work long enough on the same material to produce these features as strongly developed as they are found.

The second hypothesis recognizes the material as till but attributes its present position to transportation by floating ice. The objection to this is that there is too much of it to have been carried *en masse* and that if carried in small quantities and dropped from time to time, it should be mixed with typical marine deposits which so far have not appeared in the exposures.

The last hypothesis, and one which I am inclined most strongly to favor, is that it is a portion of the ground moraine of a great glacier that came out of the mountainous interior of Alaska, probably covering, in part at least, the basin of Hotham Inlet.

About three miles south of the mission, the modern beach ridge approaches the sea-cliff. There are no true exposures of the material in the face of the cliff, but water-worn gravel like the present beach gravel, though probably of a different origin, occurs at several points up to 50 feet above sea-level. This is the seaward edge of a small plain about 75 feet above the sea. Less than a mile south there is a smooth ridge running inland; on its south side there is another broad flat plain extending inland half a dozen miles and probably two miles wide along the sea-cliff. Its altitude is about 75 feet above the sea; on the south it is bordered by another narrow smooth ridge running inland. A few very imperfect exposures on the sea-cliff forming the seaward edge of the plain show pebbleless brown carbonaceous silt, suggesting a lagoon deposit. It is evident to me that the depressions of a rolling upland have been filled with fine silt to a level which, possibly through uplift, is now mostly about 75 feet above the sea. Marine erosion has cut away a large part of these plains and the intervening ridges, producing a sea-cliff from 50 to 100 feet high, at the foot of which lies the modern beach ridge, generally 75 yards wide. There remains to discover the composition of the upland ridges.

At about seven miles south of the mission there is a small lagoon winding about in the marshy floor of the valley whose mouth was originally below sea-level, the 75-foot silt plain above described not being developed here. Indeed, looking over the country south to beyond Cape Blossom, it appears that the smooth ridges generally rise to about 100 feet above sea-level and are separated by valleys of varying widths, generally coming down nearly to sea-level at the beach line. Inland as far as one can see there are no isolated hill peaks; nor, on the other hand, is there a suggestion that the valleys have been eroded from a plain. The topography suggests a constructional surface of a glacial type, not that of a terminal or lateral moraine, but of an undulating ground moraine.

At about half a mile south of the lagoon, the sea-cliff, 60 to 100 feet high, bisects a broad, undulating ridge which leads inland as do the others above described. Stiff blue-gray boulder clay abounding in beautifully glaciated pebbles and boulders (the latter generally gabbro or metagabbro), appears for nearly a quarter of a mile, rising from 10 to 50 feet above sea-level and overlaid by dark blue-gray and brown carbonaceous silt, 30 to 60 feet thick. I have no doubt that the core of this ridge and presumably of many others in this region is ground moraine. I am surprised and puzzled by the invariable presence over the till, even in the axes of the ridges, of stratified carbonaceous silt. I cannot distinguish between this silt formation and that which in places forms plains between the ridges. It is probable that only one silt formation is present, and that it has an attitude similar to the loess formation in the Mississippi basin, mantling an undulating drift plain. Therefore, the theory that it is a lagoon formation must be abandoned.

(At the upper edge of the bank, on the north side of the ridge south of the lagoon, I found the pelvis of a large animal. It was 8 feet wide. It had evidently been embedded in the soil at the surface of the silt formation.)

A headland about three and one-half miles northeast of the mission presents a 100-foot sea-cliff at the base of which, in places reaching up to 20 feet, occurs the blue-gray till abounding in glaciated boulders, some four feet in length. They consist chiefly of gabbro, metagabbro, pyroxenite, greenstone, diorite, gneiss, schist, marble, limestone, and fine-grained sandstone. The overlying non-pebbly carbonaceous silts form the greater portion of the cliff, but are not well exposed.

Three-fourths of a mile farther northeast, the cliff in a headland is only from 30 to 50 feet high, yet the boulder clay reaches up to 20 feet above sea-level. Boulders from one to three feet in diameter are relatively more abundant than at the outcrops before described. The largest is a dark green altered fine-grained basic volcanic rock.

At "the cape," the bold headland five miles northeast of the mission, that forms the most northerly point of the peninsula, although the sea-cliff is probably 150 feet high, the silt is so thick that the boulder clay does not appear to extend more than about 15 feet above sea-level. From the top of the cliff looking inland two peculiar depressions can be seen. They are occupied by lakes which may be between five and ten acres in extent. The northern side of each is a low valley plain, but the southern side is a crescent-shaped steep bluff. The abruptness of this bluff contrasts strongly with the flowing contours of the neighboring country. It is possible that these depressions were produced by the melting of large residual masses of glacial ice buried under the silt. I saw a similar bluff in looking over the country back of Cape Blossom.

There is nothing in the topography of the peninsula to suggest the direction of ice movement except that the ridges are prevailingly elongated easterly and westerly. These ridges, in so far as they are above sea-level, consist chiefly of silt, but, as we have seen, cores of boulder clay usually appear where they are bisected by the sea-cliff in a manner to indicate that the present topography is in large part controlled by the surface of the glacial deposit. The topography is not that typical of a terminal or lateral moraine but of a fluted ground moraine. All the till exposures examined corroborate the idea that it is ground moraine. Therefore, I incline to the opinion that these ridges are approximately parallel to the direction of ice movement like the major axis of a drumlin. Indeed, many of the shorter ridges approximate to the drumlin form, and if the silt covering were removed this form might be even more pronounced. Probably the ice that glaciated this country was a great glacier that came out of the broad valley of the Kobuk River on the east and extended into the Arctic Ocean. Mendenhall says:

> All of the peninsula which separates Hotham Inlet and Selawik Lake from Kotzebue Sound and its waters, with the exception of the extreme southwestern point (where members of the schistose series outcrop in Choris Peninsula), is made up of Pleistocene silts, clays, and embedded ice. Its outline and topography suggest that shoals which have formed off the mouths of the Noatak, the Kowak, the Selawik, and the Buckland have been raised into islands by slight local elevations, and that these islands have afterwards been tied into one long peninsula by the action of winds, waves, and currents.[1]

On the contrary, my investigation of that broad portion of the peninsula lying north of the latitude of Cape Blossom has led to the conclusion that it is a remnant of an undulating silt-covered drift plain into which the sea has cut on the western, northern, and eastern sides, producing a cliff from 30 to 100 feet high. The generally undissected character of the upland and the fresh appearance of the till suggest a late stage of glaciation presumably Wisconsin. This opinion is expressed with the fact in mind that erosion and weathering standards of the Temperate Zone are not applicable here where the subsoil is permanently frozen to great depths. Partly coincident with the later stages of cliff cutting, and partly subsequent to the completion of certain portions of the cliff, has been the formation of a modern beach ridge. All parts of the latter are undoubtedly quite recent in age. The spit on which is situated the Friends' Mission consists of several strands, or separate beach ridges, between which are marshy depressions and freshwater lakes at levels from 5 to 10 feet above the level of the sea on one side and a brackish lagoon on the other side.

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[1] U. S. Geological Survey *Professional Paper No. 10*, p. 45.

Presuming that the upland represents as late a stage as the Wisconsin epoch, the earlier stages of the sea-cliff erosion would occupy a larger part of the Recent period, the oldest of the beach ridges would be relatively modern in age and the youngest, on which the mission stands and which is yet in process of formation, would belong to a very late portion of this last epoch, perhaps the last 500 years. The marshy ground immediately behind it would be of similar youth. The age of these beach ridges and marshes is chiefly of interest in connection with the remains of large animals which occur on them.

Extending for about five miles along the northern shore of Hotham Inlet, northeast of the Pipe Spit, there is a sea-cliff from 30 to 75 feet high, interrupted by a valley one-half a mile wide. Sailing within several hundred feet of the western half of the cliff, I noticed in many exposures a stony clay of blue-gray color, doubtlessly till, extending nearly to the top of the bank. On the beach were some boulders derived from the cliff, but this is a less bouldery deposit than the till of the peninsula. Also, the till appears to be in places associated with irregularly stratified beds of sand and gravel. Landing at the eastern end of the cliff, I examined it westward for over two miles. West of the valley above-mentioned, all exposures were of stiff blue-gray till abounding in smoothed and striated pebbles and some boulders which were chiefly of limestone and calcareous schist, a few of greenish altered diorite, quartzite, gneiss, and vein quartz. There is a noticeable absence of the gabbroic rocks so prominent in the drift of the peninsula. The till extends nearly or quite to the summit of the cliff and the silt formation of the peninsula was not identified here.

The portion of the cliff east of the valley, extending about one and one-fourth miles, is made up of irregularly interbanded till and modified drift. The latter is an indistinctly stratified sand and fine gravel containing many pebbles which yet preserve traces of faceting and striation. The till is a blue-gray sandy clay containing many striated stones and a few boulders, generally of limestone. The smaller rock fragments are mostly schist, limestone, and vein quartz, a drift notably differing in composition from that of the peninsula. Any exposed section of the cliff shows one or several bands of till 5 to 15 feet thick, occurring in places at the base or top, but generally about two-thirds of the distance from the bottom. Where at the top, it forms small stony knolls in the rolling upland back of the cliff. A portion of the cliff is protected from present erosion by a raised beach whose seaward margin is a steep bank rising 10 to 15 feet above the present beach.

About ten miles farther north there is a mountain range several thousand feet high. The gently undulating plain which, near the sea-cliff, is beyond doubt a glacial plain, extends inland to the foot of this range and a smooth slope extends thence to about midway of the height of the range where it appears, in a distant view, to terminate abruptly along a line which gently rises and falls, suggesting the upper limit of glaciation. Some low ranges of hills that would be included in the glaciated area have rather smooth topography but no features which of themselves would suggest glaciation.

On the northern border of the Kobuk Delta there are in places low bluffs produced by the most northerly channel of the river swinging into a gently undulating upland. Some of this upland country occurs southwest of the mouth of this channel and is bordered by a sea-cliff on the Hotham Inlet side. I did not land at any of these bluffs and cliffs but, seen from a boat, they appear to consist of a thick bed of brown and gray sandy silt like that over the till in the peninsula, but varying to portions much more largely of sand. The rolling plain topography characterizes the lower Kobuk Valley above the delta and the country between the delta and the mountains to the north. Indeed, as far east as I have been, namely, to the Shungnak River, outside of the modern alluvial plain in which the river winds about, the valley floor is everywhere an undulating plain rising from 30 to 200 feet above the river. In the lower valley this plain appears to consist chiefly of silt, but farther east the ridges seem to be generally of coarser material, either modified drift (water-deposited sand and gravel) or of till. I did not often land at exposures of the latter, but the appearance of bluff faces at many places suggests it. I have no doubt that a careful study of this valley would bring to light moraines both terminal and lateral, but the rolling ground moraine seems to be the predominant feature of this drift.

The first decisive evidence of glaciation seen in ascending the Kobuk River is in a 150-foot bluff on the north side of the river below Squirrel River. As seen from a boat, the bluff appears to consist largely of a blue-gray stony clay, at one place resting on bed-rock. I landed at the Eskimo village at the mouth of Squirrel River and found blue-gray till exposed in the bluff. It abounds in striated stones, including a beautifully glaciated 6-foot boulder. The bank also contains much sand, probably modified drift. The north bank of the river, at a point at which I landed probably about midway between the Hunt and Ambler rivers, consists of a very stony till abounding in scratched pebbles. The country back of it has a morainic topography.

In the "Sketch Map of Alaska Showing Glacial Geology" in "The Geography and Geology of Alaska," etc., by Brooks,[1] published in 1906, the glaciated territory of the Endicott Mountain area is represented as terminating westward at about the mouth of the Ambler River, 173 miles above the mouth of the Kobuk River, and about 130 miles in a direct line from the drift near the mission on the peninsula. This is obviously an error. I traveled in the mountains near the Shungnak River, well within the reputed limit of glaciation, and while I recognized evidences of glaciation there, these evidences were not as pronounced in character as much that I saw in the lower Kobuk and Hotham Inlet regions. Similarly, on Seward Peninsula, I found in 1906 evidences of a more extensive glaciation than had been mapped by the U. S. Geological Survey in its preliminary work. I do not think that there was a general glaciation of northwestern Alaska, but that many of the valleys were occupied by glaciers that ran farther than has been indicated on the map mentioned above.

The Kobuk glacier probably occupied the entire Kobuk Valley. It may have been 230 miles long and 15 to 30 miles wide. It was probably fed chiefly from the tributary glaciers on the southern slope of the Endicott range. The limestone, schist, and vein quartz drift on the north shore of Hotham Inlet was probably dragged from the hills on the north side of the Kobuk Valley (which are known to be made up largely of such rocks); the gabbroic drift of the peninsula probably was secured in the Hotham Peak range lying south of the Kobuk Valley. If there has been no important change in the relation between land and sea, the Kobuk glacier entered the Arctic Ocean.

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[1] U. S. Geological Survey Publications, *Professional Paper, No. 45*, Pl. XXII.

BERKELEY, CAL.
April 17, 1908